22

Gifford C. Dickel

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

LOAD RELAXATION AND FRICTION LOSSES IN TWO TENDONS OF A CONTINUOUS POST-TENSIONED THREE SPAN STRUCTURE

64-16

DND JULY 1964

JUL 21 1964

MATERIALS & RESEARCH DEPARTMENT

State of California
Highway Transportation Agency
Department of Public Works
Division of Highways
Materials and Research Department

July 1964

Sect. W. O. S-6035 N

Mr. J. E. McMahon
Bridge Department
Sacramento, California

Attention: Mr. A. L. Elliott

Dear Sir:

Submitted for your consideration is a report of:

LOAD RELAXATION AND FRICTION LOSSES

IN TWO TENDONS OF A

CONTINUOUS POST-TENSIONED THREE SPAN STRUCTURE

Instrumentation performed by . . . . Structural Materials Section
Under direction of . . . . E. F. Nordlin
Work supervised by . . . . J. E. Barton and W. Chow
Report prepared by . . . . A. Sequeira

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

AS:mw
cc: LRGillis

INTRODUCTION

This investigation consisted of instrumenting two of the 38 tensioned tendons in the Route 75 Separation Bridge Structure, Contract 63-4T13C14-IP, IV-CC-75-E,Cnd. (new IV-CC-242) in Concord, California (see Figure 1). This structure is a continuous three span, prestressed concrete box girder bridge post-tensioned by a total of 38 tendons enclosed within the cells between the girder stems. The object of this investigation was to determine the friction losses along the two instrumented tendons and the minimum load left in the two tendons after load relaxation had leveled off.

The instrumentation consisted of 9 thermocouples, 20 strain gages and associated temperature compensating (dummy) gages.

This investigation was performed in cooperation with the Bridge Resident Engineer and the Bridge Department Design Section.

CONCLUSIONS

The remaining reduced loads on the tendons after relaxation are well above the required minimum of 198,000 pounds per tendon.

Due to the lubrication and the good alignment of the tendons over the saddles, friction losses were kept to a minimum of 4 x 1.2 or 4.8% from the mid-span to one end of the structure. It had been anticipated that the friction losses would exceed 10%.

If further investigations of this type are undertaken in the future, sufficient lead time should be allotted so that more efficient instruments and instrumentation techniques can be planned and developed ahead of time.

TEST PROCEDURE

A complete set of initial strain measurements on the two instrumented tendons was recorded after all 38 tendons had been initially stressed to 28,000 pounds. A 250,000 pound load was then applied to each of the 38 tendons in consecutive order. Strain readings were recorded on the experimental tendons immediately after they were stressed to 250,000 pounds. Measurements were recorded three times daily until relaxation or drop-off in tendon load had leveled off.

The two instrumented tendons and four others of the 38 tendons were then restressed and tendon load drop-off was again recorded once a month until these losses leveled off.

The last recording was taken six months after initial stressing. Temperatures were recorded each time a strain recording was taken.

DISCUSSION

The following discussion describes the instrumentation installation, test data gathering, and test data reduction involved in this investigation. The prestressing in the bridge structure consisted of post-tensioning 38 tendons which are continuous through the three spans of the structure. The two outside box girder cells or bays had 10 tendons each, and the two inside bays had 9 tendons each. Each tendon was a 1 11/16" diameter helically formed galvanized steel 69 wire bridge strand with a 1.73 square inch steel cross-sectional area. The galvanized wire strands terminated at each end of the bridge into strand sockets onto which were attached the jacking rods, thus forming a complete tendon (see Figure 2). The jacking rods which extended through holes through the end diaphragms were anchored with a Howlett anchorage assembly (see Figure 3).

The bridge structure is comprised of 3 spans totaling 534 feet. The center span is 214 feet long and the end spans are 160 feet each. Figure 5 shows the general path of the tendons passing through the bridge and also a typical section. The tendons which extend through a total of 11 diaphragms are anchored to the end diaphragms. Saddles were attached to the 9 interior diaphragms to maintain the positions of the tendons. The saddles were lubricated to minimize friction losses during the post-tensioning operations. Figure 4 shows a typical bay with ten tendons passing through one of the bent diaphragms.

Figure 6 shows one of the 400,000 pound capacity hydraulic jacks used to stress the tendons. Two load cells, which were constructed by the Materials and Research Department, were used to measure the total load applied to the tendons by the jacks. These load cells also had a 400,000 pound capacity and were used in series with the jacks on the experimental tendons.

The tendons were initially stressed to 28,000 pounds each to take up the slack. This initial load was applied with a small hydraulic jack. Load was read from a pressure gage and a pressure vs load curve for that particular jack. After the 38 tendons were initially stressed to 28,000 pounds, the next step was to install strain gages at the designated locations on the two instrumented tendons. Figure 5 shows the gage locations and the gage numbering system. Tendons #10 and #34 were used for the instrumentation and were instrumented identically.

Specifications require a minimum stress load of 198,000 pounds in each tendon. In order to obtain this minimum load, each tendon was loaded at the ends by approximately 250,000 pounds of applied load to allow for losses due to friction, creep, shrinkage, and anchorage take-up. This load was measured with the load cells. Elongations of the tendons at the ends were also measured and are tabulated in Figures 14 and 15.

Tendon strain gage measurements were recorded at the 28,000 and 250,000 pound load points and further strain measurements were taken periodically, after stressing to 250,000 pounds to check load drop-off or relaxation. These readings are recorded in Figures 14 and 15. The strain gage readings at 28,000 pounds were zero since the gages were not attached until after this load was applied.

After the load drop-off leveled off, the tendons were subjected to restressing. The load was measured when the jacks began to lift-off and free the Howlett anchorage nuts and again when the tendons were locked. Six tendons, including the two instrumented tendons, were restressed along the bridge structure before the Resident Engineer concluded that the remaining tendons did not require restressing to insure that the minimum load of 198,000 pounds per tendon remained. It should be noted that the minimum load recorded on tendon #34 before restressing was only 210,000 pounds at abutment #4. This load resulted because only 227,000 pounds had been applied to it instead of the intended 250,000 pounds due to an error in reading the load cell during the stressing operation. The stressing loads were measured with the load cells on the experimental tendons and with the pressure vs load curves of the hydraulic jacks on the other tendons. After restressing, tendon strain measurements were again taken periodically until load drop-off leveled off.

Friction losses between the tendons and the saddles were measured by anchoring one end of a tendon (dead end) and jacking the other end (live end) to 250,000 pounds. Loads on the dead and live ends were recorded with load cells. The total friction losses thus measured across the 9 saddles were 11.1%. The average friction loss across each saddle was calculated to be 1.2%, assuming equal friction losses across each saddle. Under normal conditions a tendon is jacked from both ends at the same rate. Therefore, theoretically the tendon at mid-span does not move and the maximum friction losses across only 4 saddles from mid-span to each end of the structure would be approximately 4.8%.

Thermocouples (temperature measuring devices) were embedded in the concrete in the general location of tendon #10. These thermocouples were placed on the top and bottom surface of the deck slab and the top surface of the soffit slab. Figure 5 shows the locations of the thermocouples (TC). Figure 7 shows a TC installation on the deck. Figure 8 is a table of all the recorded temperature measurements.

STRAIN GAGE INSTALLATION

Baldwin FAN-25-12, S6-L strain gages were used on the wires of the post-tension tendons. This type of strain gage is an epoxy backed gage with a length of 0.25 inches and a width of 0.025 inches. This type of gage was most suitable because it is small enough to fit on the wires.

Each tendon was stressed up to 28,000 pounds to remove the slack and then anchored. The zinc coating on the instrumented tendon wires was scraped off in the area to be instrumented and the area was sanded with #180 grit paper. After the zinc coating was thoroughly removed from the surface, acetone was used to remove any grease and dirt that might have been left on the bare metal. Two strain gages were installed at each location on the instrumented strands. These were placed on two adjacent wires of the strand. The strain gages were glued to the wires with EPY-150 epoxy. After a curing period of about four hours, leads were attached to the two strain gages. Belden type 8434 plastic insulated 4-conductor lead wire was used. The black and white leads (BW) were soldered to one gage and the red and green leads (RG) were soldered to the other gage (see Figure 9).

A waterproofing epoxy compound was applied to the strain gage and the leads to keep out moisture. The compound also provided mechanical protection to the strain gage. Before the waterproofing epoxy was applied, an MIBK primer solution was applied to the plastic insulation of the lead wires so that the waterproofing epoxy would adhere. The waterproofing epoxy was a two-part epoxy-Thiokol mixture. It consisted of two separately bulk-packaged mixtures. One part by weight of Mixture #1 was mixed with two parts by weight of Mixture #2. The mixtures consisted of:

Mixture #1

Shell Epon Resin 828	91.0%
Cab-O-Sil, Uncompressed	9.0%

Mixture #2

Thiokol LP-3	86.8%
DMP-30	5.1%
Cab-O-Sil, Uncompressed	8.1%

The mixture in its uncured state is like a heavy grease paste and does not sag. It cures to a solid elastic material. The mixture was applied to the strain gages and up onto the lead wires. A megometer was used to make sure that the strain gage was not grounded to the steel wires.

Temperature compensating (dummy) gages were installed at each strain gage location to compensate for any temperature changes in the structure and also to complete the electrical bridge circuit. The temperature compensating gage consisted of gluing the same type of strain gage as used on the job to a piece of reinforcing bar. These temperature compensating gages were placed directly below the measuring gage and taped to the tendon to hold them in place (see Figure 12).

Baldwin A-5-1 strain gages were used on the jacking rods. Since the jacking rods are large in diameter, this larger strain gage could be used.

Strain gages were attached to the jacking rods by first using acetone to dissolve and wipe away the rust inhibitor and lubricating grease that was applied to the jacking rods before installation. Then a file was used to clean an area large enough to place one longitudinal and one transverse strain gage. The strain gage installation generally was the same as on the strand except that the two gages were wired up in a half bridge circuit so that the longitudinal gage was the active or measuring gage and the transverse gage was the dummy or temperature compensating gage (see Figure 10). Figure 11 shows the completed strain gage installation on one of the jacking rods.

CALCULATIONS

Three methods for determining loads along a tendon were considered before doing any instrumentation work on the bridge.

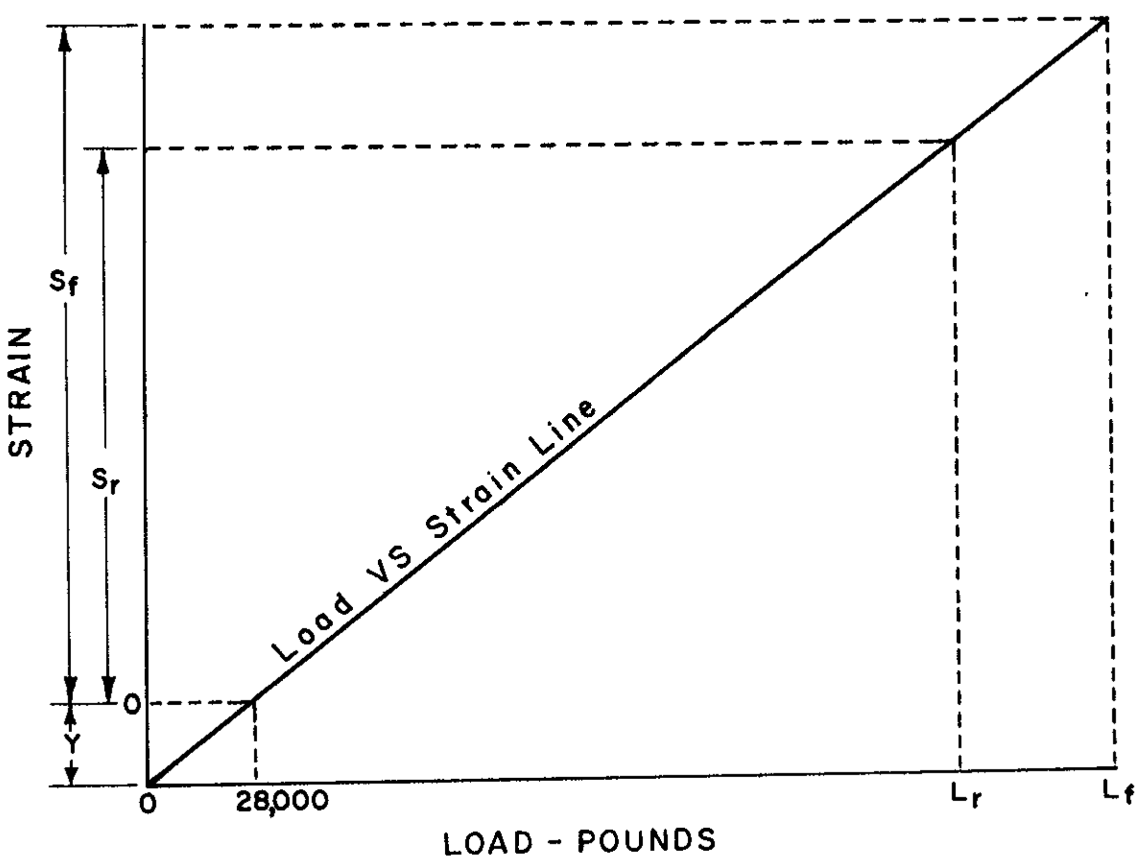
The first and the most accurate method was to install load cells at each location where a load reading was desired. However, in order to do this the tendon would have to be cut at the designated locations and strand sockets installed so that a load cell could be inserted. At the time when this research project was discussed, the tendons were already in place in the structure. The strand end sockets were installed at the factory (this can be accomplished by knowing the exact length of the bridge). Constructing and installing the load cells and resocketing the ends by this method would have caused considerable delay to the contractor and would have been more expensive. However, had this instrumentation investigation been planned earlier, this method could have been used. In this case it was decided to sacrifice some accuracy and use a quicker, less costly method.

The second method considered was to install strain gages on the tendon and use the elongation vs load curves supplied by the manufacturer to determine the loads. Figures 16 and 17 are two such curves supplied by the manufacture of the strands used in this structure. The two curves were developed from lab tests on two 100 inch long specimens taken from two reels of the strand. This method was not used because of past experience that the modulus of elasticity is not uniform over the length of a strand.

For example, at 246,000 pounds of load one test specimen showed a modulus of elasticity of 25,070,000 pounds per square inch while the other specimen showed a modulus of elasticity of 25,570,000 pounds per square inch. Since strain gages would have to be used to measure elongation and since elongation is inversely proportional to the modulus of elasticity, there is a difference of 2% between the two specimens. This difference is already greater than the friction loss calculated over one saddle which is only 1.2%. Further evidence that the modulus of elasticity varies in a given specimen is shown in Figures 14 and 15. At each gage location two strain gages (BW and RG) were glued on two adjacent wires to measure elongation. The differences of the two strain gage readings varied from 1.8% to 12.1%. Full load strain readings from the two gages at location 34-11, for example, were 4920 and 4390 microinches per inch. This would represent a difference of 12.1%. Full load strain readings at location 10-13 were 4480 and 4560 microinches per inch, representing a difference of 1.8% which still was higher than the friction losses over one saddle. Since friction was also to be determined, this method was not considered accurate enough.

The third method and the one used in this investigation was to first determine the total friction loss through the

9 diaphragms and then assume an average friction loss through each diaphragm. This was done as stated in the discussion portion of this report. With the approximate friction loss known at each diaphragm, the initial full loads can be determined at desired locations on the tendons by knowing the full loads applied at the jacking rods and deducting for the intermediate friction losses. This would only apply when the tendons are being stressed to initial full load. The subsequent relaxed loads at given points in the tendons can then be calculated from the change of strain recorded in the tendons at the same points during the load drop-off period. Since strain gages were applied to two adjacent wires of the stranded tendons at each instrumented location, it can be assumed that the strain in the tendon at each location is represented at any time by the average of the two strain gage readings. The percentage of load loss in a tendon at any point during any period will be the percentage of average strain loss recorded in the tendon at the same point during the same period. On this basis, the following formula was developed to determine the subsequent reduced load at a given point in a tendon at any recorded time.



Refer to graph above. It is noted that a correction factor will have to be employed to determine true percentage drop-off in strain due to the fact that the initial strain reading or zero strain recording was taken at 28,000 pounds on each tendon.

L_r = Remaining reduced load in pounds on tendon at given instrumented location.

L_f = Initial full load in pounds on tendon at given location.

S_r = Remaining reduced strain recorded on tendon at given location.

S_f = Initial full load strain recorded on tendon at given location.

Y = Unrecorded initial strain.

Assuming a straight line load vs. strain curve in the graph and by similar triangles, $L_r/(S_r+Y) = L_f/(S_f+Y)$. Since L_r is the required load, $L_r = L_f\ (S_r+Y)/(S_f+Y)$. L_f, S_r, and S_f are known quantities, but Y will have to be determined. Again by similar triangles $Y/28{,}000 = (Y+S_f)/L_f$ or $Y = 28{,}000\ S_f/(L_f-28{,}000)$, by substituting for Y in equation $L_r = L_f\ (S_r+Y)/(S_f+Y)$, $L_r = [S_rL_f+(28{,}000)(S_f-S_r)]/S_f$. This then is the formula used to determine the subsequent or remaining reduced loads on the tendons after load drop-off or relaxation had occurred.

In summary, the loads on the tendons were calculated as follows: Refer to Figure 13 for loads. The initial loads on the jacking rods at locations 10 and 20 were measured with the load cells less a correction for anchorage take-up determined by strain gage readings. The loads on the tendons at locations 11, 12, and 13 were the differences between the jacking rod load and the friction losses (which was mentioned earlier) across each saddle. These loads are recorded on row 1, Figure 13.

Row 2 at each instrument point on Figure 13 is the remaining reduced load prior to retensioning. The loads on the jacking rods at points 10 and 20 were measured with load cells just as the jacks began to lift-off and loosen the Howlett anchorage nuts. The loads on the tendons at points 11, 12, and 13 were calculated from a percentage drop-off in strain from the original load on the tendon.

Row 3 shows the load after the retensioning process. The jacking rod loads at points 10 and 20 in each tendon were measured with load cells and the loads at points 11, 12, and 13 in each tendon were calculated from the percentage drop-off in strain from the original load on the tendon.

Row 4 represents the load remaining at the five points on the tendons at the last recording. All loads were calculated from a percentage drop-off in strain from the original loads. Figures 14 and 15 show the strains observed in the two instrumented tendons recorded in tabulated form.

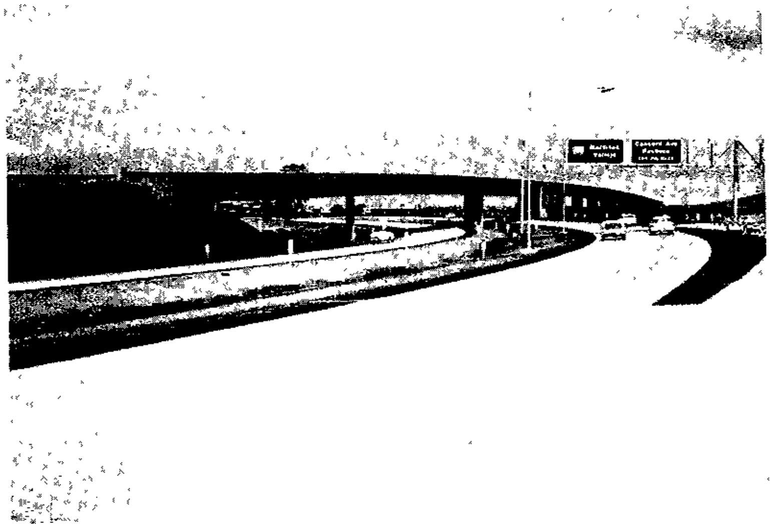


Figure 1.

Over-all view of bridge structure.

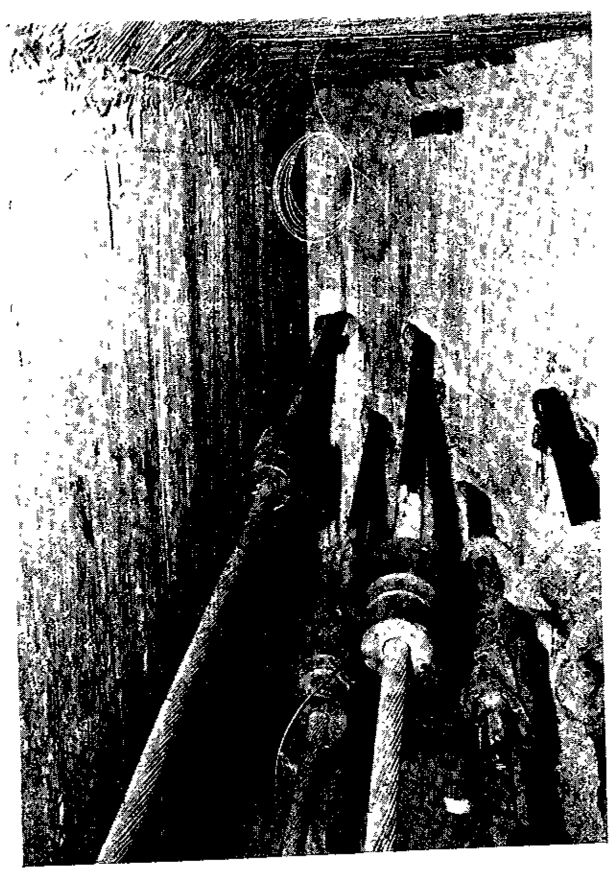


Figure 2.

Strand sockets and jacking rods.

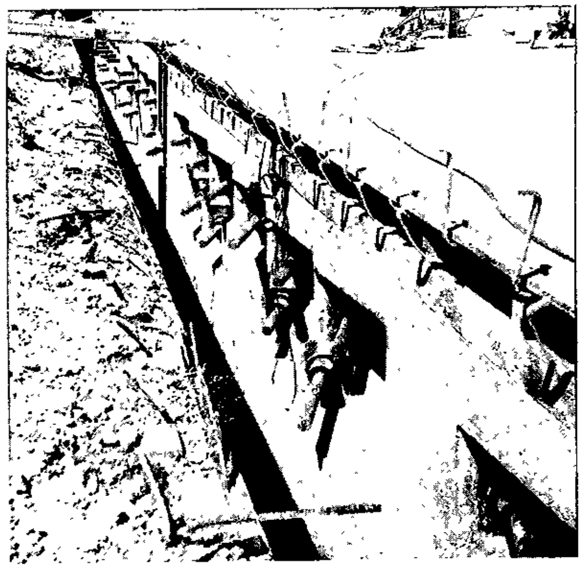


Figure 3.

Howlett anchorage assembly.

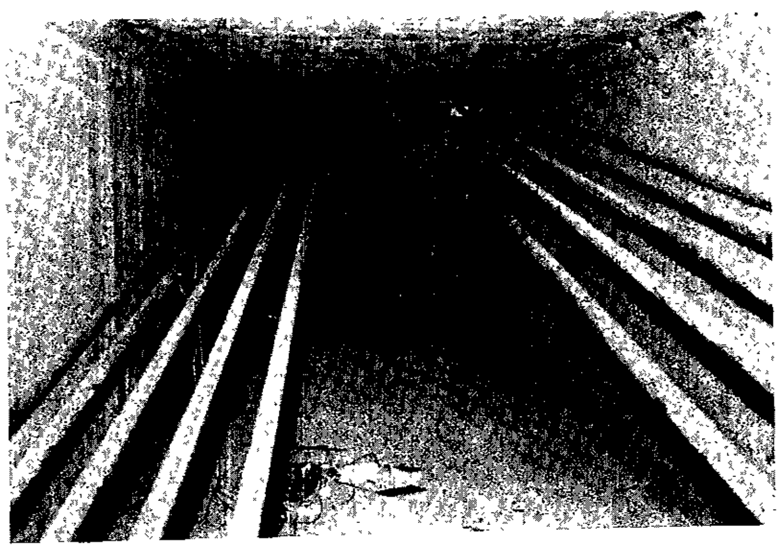
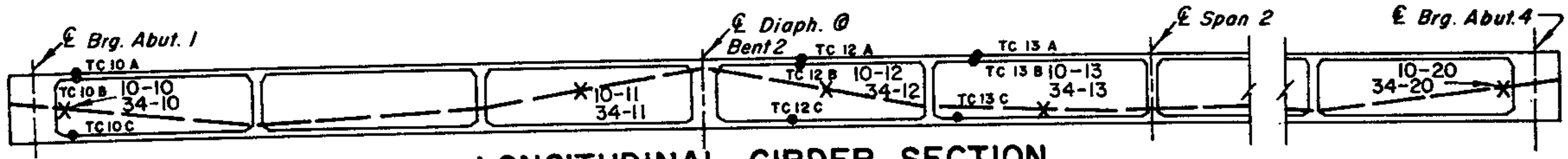


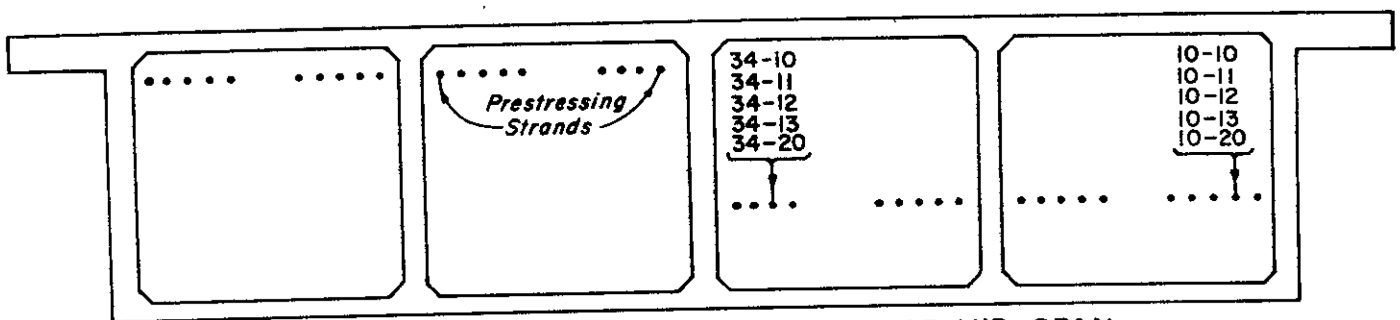
Figure 4.

General path of tendons in one section of bay.

FIGURE 5



LONGITUDINAL GIRDER SECTION



NEAR BENT

NEAR MID-SPAN

TYPICAL SECTION

EXPLANATION

X 10-10, 10-20	Strain Gages on Tendon #10 Jacking rod
X 34-10, 34-20	Strain Gages on Tendon #34 Jacking rod
X 10-11, 10-12, 10-13	Strain Gages on Tendon #10
X 34-11, 34-12, 34-13	Strain Gages on Tendon #34
● TC-10A	Thermo couple location

NO SCALE

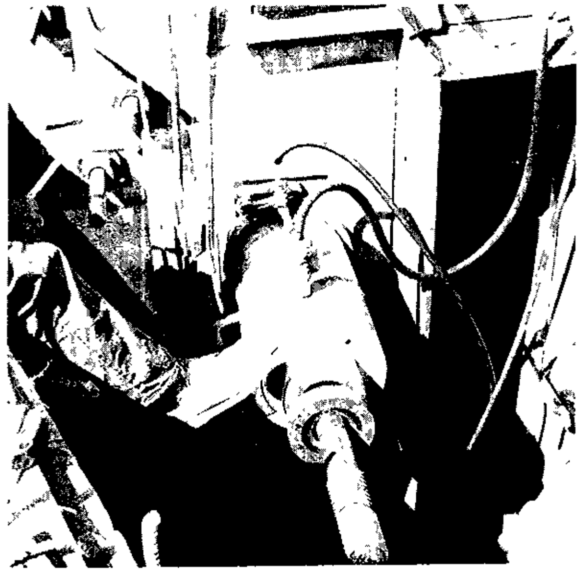


Figure 6.

400,000 pound capacity hydraulic jack.

Figure 7.

A typical thermocouple installation.

FIGURE 8

Temperature ° F.

Date	Time	10-A	10-B	10-C	12-A	12-B	12-C	13-A	13-B	13-C
8-19-63	0920	74	74	76	78	76	74	80	76	76
	1230	101	83	77	101	82	76	102	87	84
	1500	112	96	81	112	96	84	113	98	83
8-20-63	0800	70	70	76	76	76	78	76	74	78
	1030	90	78	78	90	80	80	90	80	80
	1500	104	85	88	116	100	85	118	100	87
8-21-63	0800	71	70	74	71	71	76	71	71	76
	1030	92	75	75	92	80	80	88	80	80
	1230	100	86	80	106	86	81	106	87	81
	1500	110	94	80	116	96	81	116	100	84
8-22-63	0730	68	68	71	68	68	73	68	68	73
	1230	79	72	70	90	76	74	90	78	76
	1500	96	79	73	100	86	78	100	88	78
8-23-63	0830	67	64	67	67	64	67	67	64	69
	1630	92	82	70	92	82	72	92	82	72
8-24-63	0930	68	62	65	68	62	68	68	62	68
	1200	82	72	68	92	74	70	92	76	72
	1500	95	84	70	103	86	75	105	90	73
8-25-63	0800	64	64	67	64	64	67	64	64	67
	1200	96	80	72	96	78	73	96	78	70
	1500	105	90	75	105	90	75	105	90	76
8-26-63	0830	70	66	70	70	69	74	70	70	74
	1230	100	83	74	102	82	76	102	84	76
	1530	116	96	80	116	100	82	116	100	82
8-30-63	1000	78	70	70	80	70	72	80	70	70
9-6-63	1000	86	74	70	88	72	72	90	74	72
9-12-63	1000	*	74	74	*	72	70	*	72	70
10-7-63	1000	*	66	66	*	68	68	*	68	68
11-12-63	1000	*	56	56	*	56	56	*	56	56
12-24-63	1000	*	42	41	*	40	40	*	40	40
3-24-64	1000	*	56	54	*	57	55	*	44	55

* Thermocouples wiped off deck.

Temperature ° F.

Date	Time	10-A	10-B	10-C	12-A	12-B	12-C	13-A	13-B	13-C
8-19-63	0920	74	74	76	78	76	74	80	76	76
	1230	101	83	77	101	82	76	102	87	84
	1500	112	96	81	112	96	84	113	98	83
8-20-63	0800	70	70	76	76	76	78	76	74	78
	1030	90	78	78	90	80	80	90	80	80
	1500	104	85	88	116	100	85	118	100	87
8-21-63	0800	71	70	74	71	71	76	71	71	76
	1030	92	75	75	92	80	80	88	80	80
	1230	100	86	80	106	86	81	106	87	81
	1500	110	94	80	116	96	81	116	100	84
8-22-63	0730	68	68	71	68	68	73	68	68	73
	1230	79	72	70	90	76	74	90	78	76
	1500	96	79	73	100	86	78	100	88	78
8-23-63	0830	67	64	67	67	64	67	67	64	69
	1630	92	82	70	92	82	72	92	82	72
8-24-63	0930	68	62	65	68	62	68	68	62	68
	1200	82	72	68	92	74	70	92	76	72
	1500	95	84	70	103	86	75	105	90	73
8-25-63	0800	64	64	67	64	64	67	64	64	67
	1200	96	80	72	96	78	73	96	78	70
	1500	105	90	75	105	90	75	105	90	76
8-26-63	0830	70	66	70	70	69	74	70	70	74
	1230	100	83	74	102	82	76	102	84	76
	1530	116	96	80	116	100	82	116	100	82
8-30-63	1000	78	70	70	80	70	72	80	70	70
9-6-63	1000	86	74	70	88	72	72	90	74	72
9-12-63	1000	*	74	74	*	72	70	*	72	70
10-7-63	1000	*	66	66	*	68	68	*	68	68
11-12-63	1000	*	56	56	*	56	56	*	56	56
12-24-63	1000	*	42	41	*	40	40	*	40	40
3-24-64	1000	*	56	54	*	57	55	*	44	55

* Thermocouples wiped off deck.

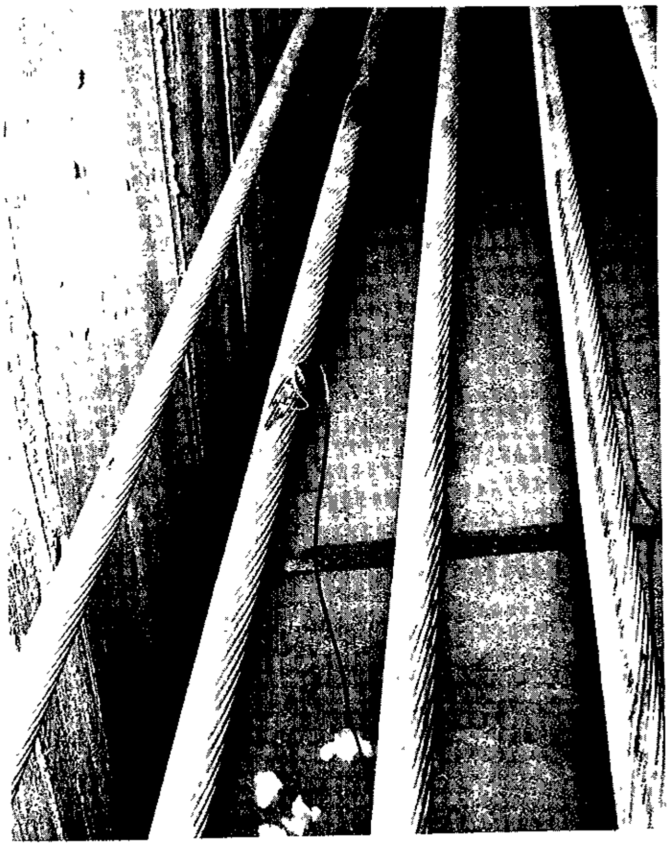


Figure 9.

Two wired strain gages on tendon.

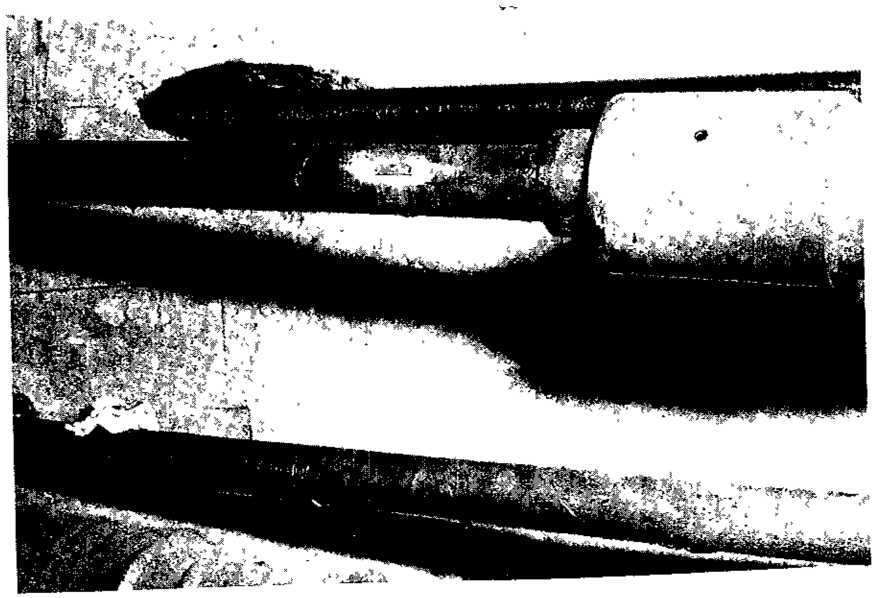


Figure 10.

Two strain gages on jacking rod.

Figure 11.

Completed strain gage installation on jacking rod.

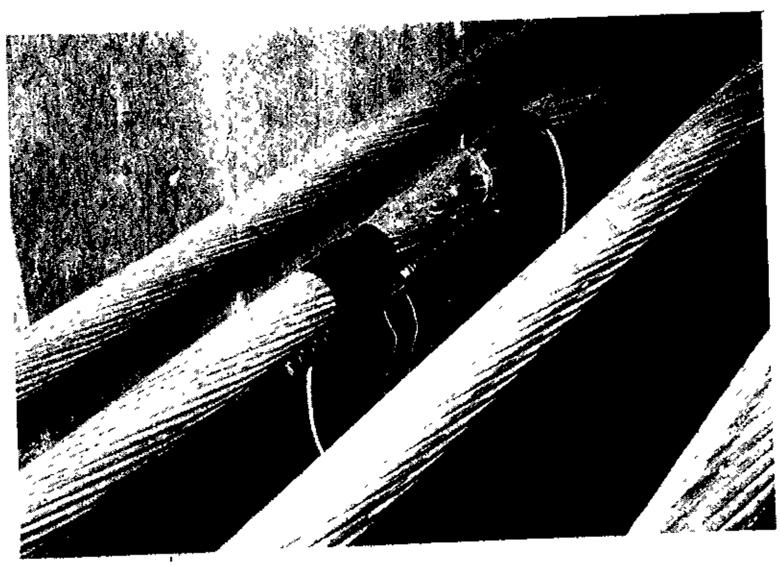
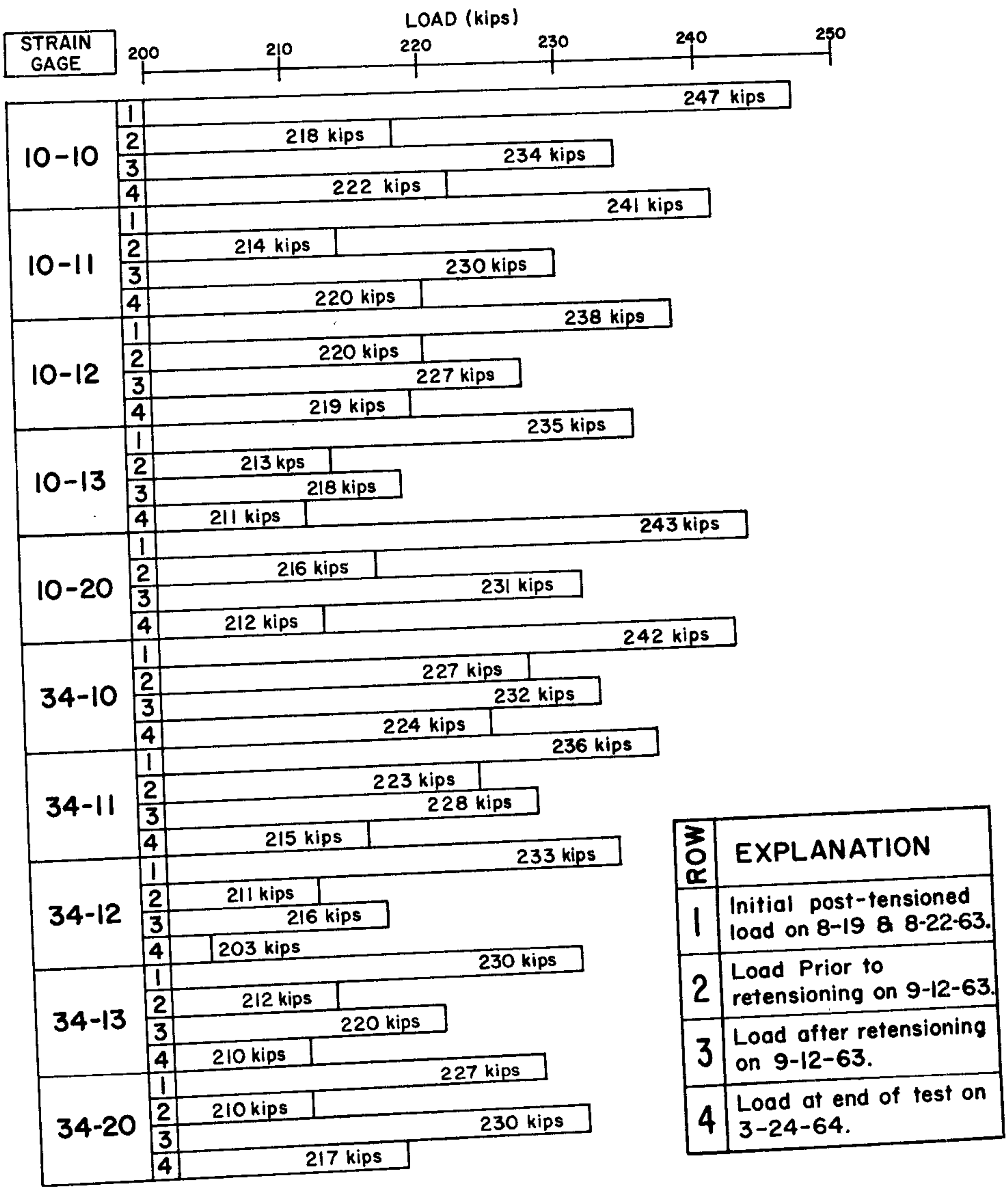


Figure 12.

Completed strain gage installation on tendon.

FIGURE 13

SUMMARY OF POST-TENSIONED TENDON LOADS



STRAIN READINGS ON TENDON #10

Date	Time	* 10-10 * Strain	10-10 Elong. in in.	** 10-11 BW	** 10-11 RG	** 10-12 BW	** 10-12 RG	** 10-13 BW	** 10-13 RG	* 10-20 Elong. in in.	* 10-20 * Strain	Remarks
8-19-63	1040	1860	18¼							16 7/16	1815	(1)
	1050	1810		4695	4830	4775	4580	4480	4560		1745	(2)
	1500	1740		4575	4770	4765	4540	4370	4490		1705	
8-20-63	0830	1695		4465	4685	4725	4500	4250	4390		1650	
	1030	1700		4475	4700	4715	4510	4255	4395		1665	
	1500	1865		4470	4690	4705	4490	4280	4430		1700	
8-21-63	0830	1670		4415	4640	4685	4470	4190	4340		1635	
	1030	1670		4415	4640	4665	4465	4195	4340		1635	
	1230	1670		4415	4640	4665	4455	4220	4370		1635	
	1500	1670		4425	4655	4670	4465	4230	4390		1635	
8-22-63	0730	1645		4335	4570	4625	4420	4125	4290		1620	
	1230	1650		4345	4580	4625	4410	4140	4300		1620	
	1500	1645		4335	4570	4605	4400	4150	4310		1620	
8-23-63	0830	1630		4275	4575	4565	4370	4060	4220		1600	
	1630	1635		4295	4535	4565	4375	4090	4250		1600	
8-24-63	0910	1630		4240	4480	4530	4335	4030	4190		1595	
	1200	1645		4255	4495	4535	4335	4050	4220		1595	
	1500	1630		4225	4470	4515	4320	4065	4235		1585	
8-25-63	0800	1650		4175	4410	4465	4280	3980	4150		1585	
	1200	1620		4205	4450	4495	4300	4030	4200		1585	
	1500	1660		4215	4450	4485	4310	4050	4225		1585	
8-26-63	0830	1600		4165	4405	4465	4270	3990	4175		1545	
	1230	1610		4175	4420	4470	4280	4020	4205		1540	
	1530	1610		4190	4430	4475	4290	4060	4245		1545	
8-30-63	1000	1570		4125	4360	4415	4230	3940	4140		1530	
9-6-63	1000	1570		4075	4320	4385	4200	3950	4170		1515	
9-12-63	1045	1560		4045	4290	4365	4180	3925	4160		1500	
	1100	1685		4385	4640	4550	4330	4065	4265		1610	(3)
10-7-63	1000	1640		4285	4550	4460	4290	4010	4290		1570	
11-12-63	1000	1650		4225	4500	4410	4240	3920	4250		1550	
12-24-63	1000	1610		4215	4490	4395	4230	3810	4160		1550	
3-24-64	1000	1585		4165	4420	4340	4170	3810	4200		1465	

* Strain to be divided by 1+ Poisson's Ratio to obtain strain in microinches per inch.

** Strain in microinches per inch.
10-11 BW, 10-11 RG Two adjoining strain gages at one location.

(1) Before jacks were released.
(2) After jacks were released.
(3) Restressed.

FIGURE 14

STRAIN READINGS ON TENDON #34

Date	Time	* 34-10 * Strain	34-10 Elong. in in.	** 34-11 BW	** 34-11 RG	** 34-12 BW	** 34-12 RG	** 34-13 BW	** 34-13 RG	* 34-20 Elong. in in.	34-20 * Strain	Remarks
8-22-63	0730	1915	17 5/16							15	1770	(1)
	1730	1865		4920	4390	4500	4145	4295	4455		1740	(2)
8-23-63	0830	1775		4880	4300	4370	3930	4230	4265		1690	
	1630	1750		4890	4310	4400	3740	4245	4275		1680	
8-24-63	0910	1750		4825	4245	4330	3870	4215	4210		1655	
	1200	1735		4810	4240	4330	3880	4205	4210		1650	
	1500	1750		4840	4260	4350	3800	4240	4235		1660	
8-25-63	0800	1720		4780	4200	4280	3810	4145	4135		1650	
	1200	1710		4790	4210	4300	3830	4185	4170		1645	
	1500	1715		4820	4240	4280	3820	4180	4165		1645	
8-26-63	0830	1700		4780	4190	4270	3790	4135	4105		1630	
	1230	1690		4780	4200	4260	3790	4165	4135		1630	
	1530	1705		4795	4225	4290	3820	4185	4145		1640	
8-30-63	1000	1670		4710	4140	4175	3700	4105	4035		1600	
9-6-63	1000	1650		4650	4100	4150	3670	4065	3985		1580	
9-12-63	1000	1635		4640	4100	4120	3640	4035	3945		1570	
	1045	1660		4760	4200	4210	3730	4205	4105		1720	(3)
10-7-63	1000	1615		4650	4140	4150	3650	4155	4035		1670	
11-12-63	1000	1600		4550	4040	4070	3570	4085	3965		1645	
12-24-63	1000	1600		4480	3990	4015	3520	4065	3935		1650	
3-24-64	1000	1595		4420	3965	3960	3460	4015	3875		1610	

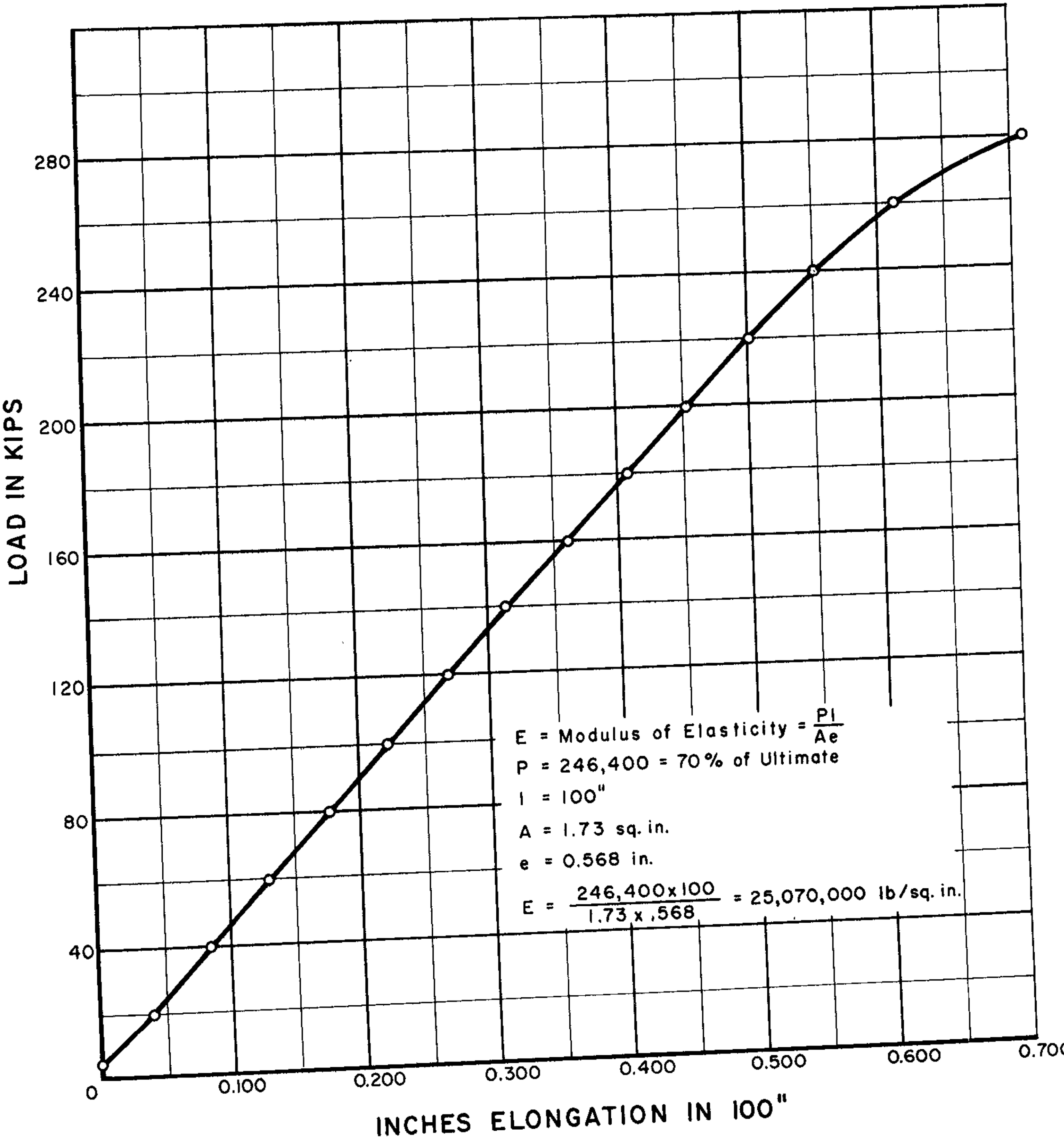
* Strain to be divided by 1+ Poisson's Ratio to obtain strain in microinches per inch.
** Strain in microinches per inch.

(1) Before jacks were released.
(2) After jacks were released.
(3) Restressed.

FIGURE 15

ELONGATION VS LOAD CURVE

$1\frac{11}{16}$" DIA. 69 WIRE GALV. STEEL BRIDGE STRAND



ELONGATION VS LOAD CURVE

$1\frac{11}{16}$" DIA. 69 WIRE GALV. STEEL BRIDGE STRAND